Evaluation of ERTS-1 Imagery for Mapping Quaternary Deposits and Landforms in the Great Plains and Midwest 1/ (SR 238)

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Type 1 Progress Report

ERTS-1

A. Evaluation of ERTS-1 imagery for mapping Quaternary deposits and landforms in the Great Plains and Midwest.

ERTS-1 Proposal No. SR 238.

B. GSFC ID No. of Principal Investigator: IN 404

C. Problems encountered:

The major problem that still impedes progress on the project is the weather in the Midwest and Great Plains. Extensive cloud cover and atmospheric haze degrade much of the imagery. Some of the potential study areas are still not completely covered by good images.

D. Accomplishments during the reporting period:

Preliminary field investigation of anomalies revealed by ERTS imagery was started in Missouri in February with Dr. William Allen, of the Missouri Geological Survey. The results of this and further field investigations will be reported at a later date. The anomalies may indicate relicts of end moraines formed by middle or early Pleistocene glaciers.

A general discussion of ERTS investigations in the Midwest was held with the staff of the Missouri Geological Survey and with local members of the U. S. Geological Survey.

The earlier phases of a six-phase program of analysis (outlined in the 1 January 1973 Type II report and repeated here as Appendix A) are being continued in the various study areas. Phase-1 analysis consists of interpreting landform and land-use characteristics and surficial geologic materials from the ERTS images alone, without using additional data. We adopted a basic format for the phase-1 maps and map explanations, illustrated by the maps and map explanation included with this report.

For identification and mapping of landforms, topographic information obviously is needed. In airphoto interpretation, this information is obtained most fully by stereoscopic viewing. Unfortunately, the ERTS images provide rather limited capability for such viewing, particularly in the Great Plains-Midwest. True stereovision is not provided by the 10% end-lap of consecutive frames along a track (the same scan lines appear in the overlapping areas of both frames). Stereovision is possible where frames from adjacent orbital tracks side-lap with each other; commonly 40 to 60% of a frame has such side-lap coverage. However, the limited parallax resulting from the high orbital altitude, together with the low relief in most of the Great Plains-Midwest, severely restricts the usefulness of stereoscopic viewing of ERTS images for geologic-terrain interpretation in this region. Consequently, landforms must be interpreted largely from land uses.

Land uses can be deduced from tonal (gray-level or density), pattern, and "textural" variations in the images. Landforms and landform associations are interpreted primarily from agricultural patterns, including not only field patterns, but also the patterns of pasturelands, woodlands, and rural roads. The size of fields and the regularity of their shapes (square or rectangular vs. irregular) are controlled by the topography. Concentrations of very large (greater than 160 acres) fields with regular shapes and sharp boundaries generally indicate areas of very low relief and low drainage density, such as broad flood plains and flat or gently undulating tabular uplands. The distribution of woodlands provides much information on the character of valleys and escarpments. In the areas of good soils, woodlands are restricted to slopes too steep to be farmed, i. e., the steeper valley sides. In the more arid parts of the region the steeper slopes commonly are partly woodland or brushland and partly pastureland.

Landform characteristics also can be interpreted indirectly from analysis of stream density, stream dissection and drainage patterns, and stream-divide relations--again mainly as revealed by land-use patterns, supplemented where possible by stereoviewing. It is important to make these higher levels of landform interpretation because only through them is it possible to detect anomalies that may point to the more ancient and obscure features that we are looking for, such as "palimpsests" of ancient moraines and buried river valleys. Detecting landform anomalies from ERTS images of the Great Plains-Midwest is more difficult than in regions of higher relief, less vegetative cover, and less atmospheric haze.

Interpretation of the surficial geologic materials involves secondary and tertiary levels of inference; hence, specific interpretations cannot be made at the phase-1 level, but must await the higher phases of analysis, including various kinds of "ground-truth" control. Nevertheless, some general inferences obviously can be made at the phase-1 level, for example, where the landform morphology indicates the underlying materials, as with alluvial lowlands and sand dunes.

Examples of phase-1 maps are given below.

Grand Island, Nebraska, study area (fig. 1).

The Grand Island 1° x 2° study area is fairly uncomplicated, with several of the landform associations characteristic of the unglaciated central Great Plains. In its northern part are broad lowlands along the Platte River. The uplands are wide, gently undulating to nearly level loess-mantled plains, little dissected by streams. The map units show how differences in the degree of dissection can be a clue to the relative age of the land surface and the underlying deposits. Other items of interest (which are subject to verification in the higher phases of analysis) are the possible sandhills (outliers of the extensive Nebraska Sand Hills), and the modern flood plain of the Platte River, which may be the result of recent changes in the regimen of the river.

Fremont, Nebraska, study area (fig. 2).

The Fremont 1° x 2° study area is typical of the transition zone between the unglaciated Great Plains and the glaciated area of eastern Nebraska. Approximately the eastern half of the area was glaciated during the early and middle Pleistocene. The broad lowlands of the Platte River extend through the central part of the area and the Missouri River lowlands through the northeastern part. The upland plains are loess-mantled and vary from broad, gently undulating interstream areas, with widely spaced, shallow stream valleys, to intricately dissected uplands, with closely spaced streams and rather narrow interfluves.

The Todd Valley, in the eastern half of the map area, is an abandoned river channel associated with the Platte River. This valley and the pronounced terrace north of the Platte (map unit 1b) can best be distinguished from lower (younger) alluvial lowlands (map units 1 and 1a in figure 2) on two fall images, 1076-16384 (7 October 1972) and 1095-16445 (26 October 1972), apparently because of less vegetative cover than in summer images. Moreover, valley lowland and terrace units can be distinguished most clearly on infrared bands of the 7 October image (which unfortunately covers only the eastern one-third of the study area). Three days of moderate rain fell before this image was taken. This may have produced differences in soil moisture, and consequently, in infrared reflectance, that enhanced the relatively subtle differences in soil associations between these map units. This finding is worth exploring for possible application in improving multispectral techniques for detailed mapping of soils and surficial deposits.

A possible ancient moraine-controlled drainage divide has been extended into the southern part of the Fremont study area from the Lincoln study area, analysis of stream patterns. This divide cannot properly be called a moraine, because this term refers to a landform, composed mainly of till, whose original constructional morphology is still well preserved. This divide is much eroded and loess-mantled, and may be a relict of a moraine or moraine system of middle or early Pleistocene age, perhaps modified by ice-margin drainage diversions.

Figure 1. Phase-1 preliminary map of the Grand Island, Nebraska, study area.

Explanation

Map unit	Landform characteristics	Land-use characteristics	Surficial-geologic materials
1.	Valley lowlands - flood plains and low terraces along major streams. Single heavy lines denote minor streams with distinguishable valley lowlands.	Fields very large and regular, mainly irrigated crop land and some pasture.	Alluvial deposits of late Quaternary age. Some terraces may be loess mantled.
1a.	Modern flood plain of the Platte River.	Area is darker and more uniform in tone on bands 5 and 7, than map unit 1. Probably some tree cover and pasture. Possibly frequently flooded.	Alluvium, of late Holocene age.
2.	Plains with gently undulating interstream uplands. Streams widely spaced and not deeply entrenched.	Fields large to moderate in size and regular in shape. Mainly irrigated cropland with some pasture, and a few isolated center-pivot sprinkler irrigation systems.	Probable extensive loess veneer, over other deposits of Pleistocene and older age.
2a.	No pronounced physiographic difference from unit 2 is evident; however, there are considerable tonal differences on frame 1060-16503 (21 September 1972), in bands 6, 7, and especially 5. These differences may indicate landforms and deposits gradational from sandhills (unit 5) to the loess-covered plains (unit 2), or they may be caused by unexplained differences in surficial deposits or irrigation practice	Land-use patterns generally are like unit 2, but possibly there is less irrigated land. Many more center-pivot, sprinkler irrigation systems are present.	Probable extensive loess veneer and local eolian sand over other deposits of Pleistocene and older age.
3.	Intermediate between units 2 and 4. Streams are more closely spaced than in unit 2, but the interfluves are broader than in unit 4.	Field patterns on the main interfluves are moderately large and regular; elsewhere they are either irregular, vaguely discernible, or indiscernible. Probably a mixture of irrigated and dryland agriculture, both crop land and pasture.	Probable extensive loess veneer over older deposits of Pleistocene and older age.
4.	Plains with closely spaced, moderately entrenched streams and narrow interstream uplands. The tributary streams are short and nearly at right angles to major streams, such as the Republican River.	Fields are small and irregular, often only vaguely discernible, which suggests mainly dry-land farming and some rangeland; a few center-pivot sprinkler irrigation systems are present.	
5.	Sandhills. Tone and texture suggest isolated sandhills, and swell-and-swale dune topography. There are no well-developed large-dune forms.	Mainly rangeland and pasture, with some center-pivot sprinkler irrigation systems.	Eolian sand.
5a.	Possible sandhills (small, isolated, and poorly defined).	Land-use patterns are generally obscure. The area is characterized by a uniform gray tone on the imagery.	
6.	Prominent escarpment (barbs point up-scarp).	Usually marked by a sharp change in tones and land-use patterns.	
7.	Minor streams with narrow valley lowlands distinguishable on ERTS images. (See unit 1)		
8.	Lakes and reservoirs.		

Images used (bands 5 and 7):

1043-16555
1060-16500
1060-16503
1095-16445
1095-16451
1096-16510
1032-16512

Figure 1. Phase-I Preliminary Map of the Grand Island, Nebraska, Study Area

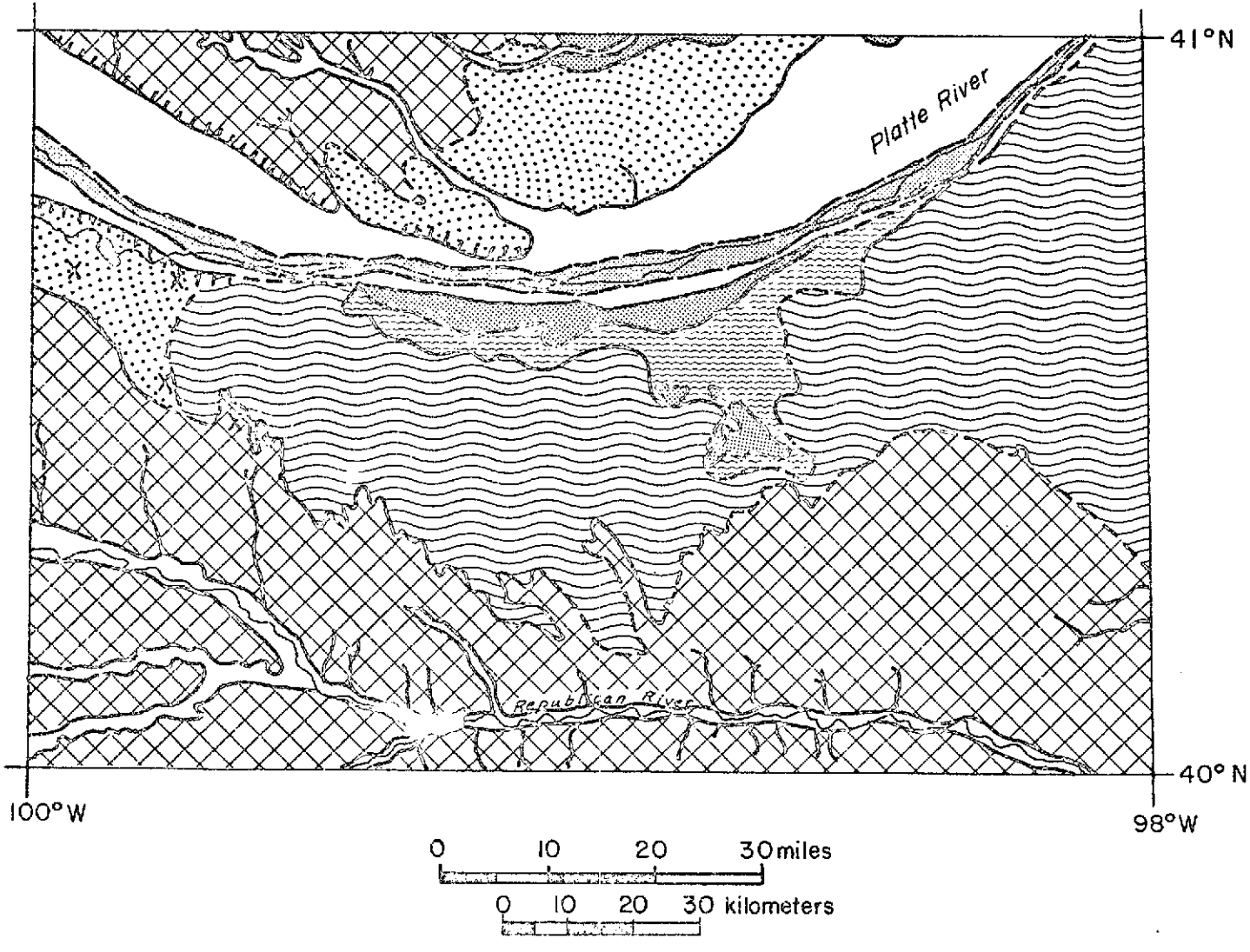
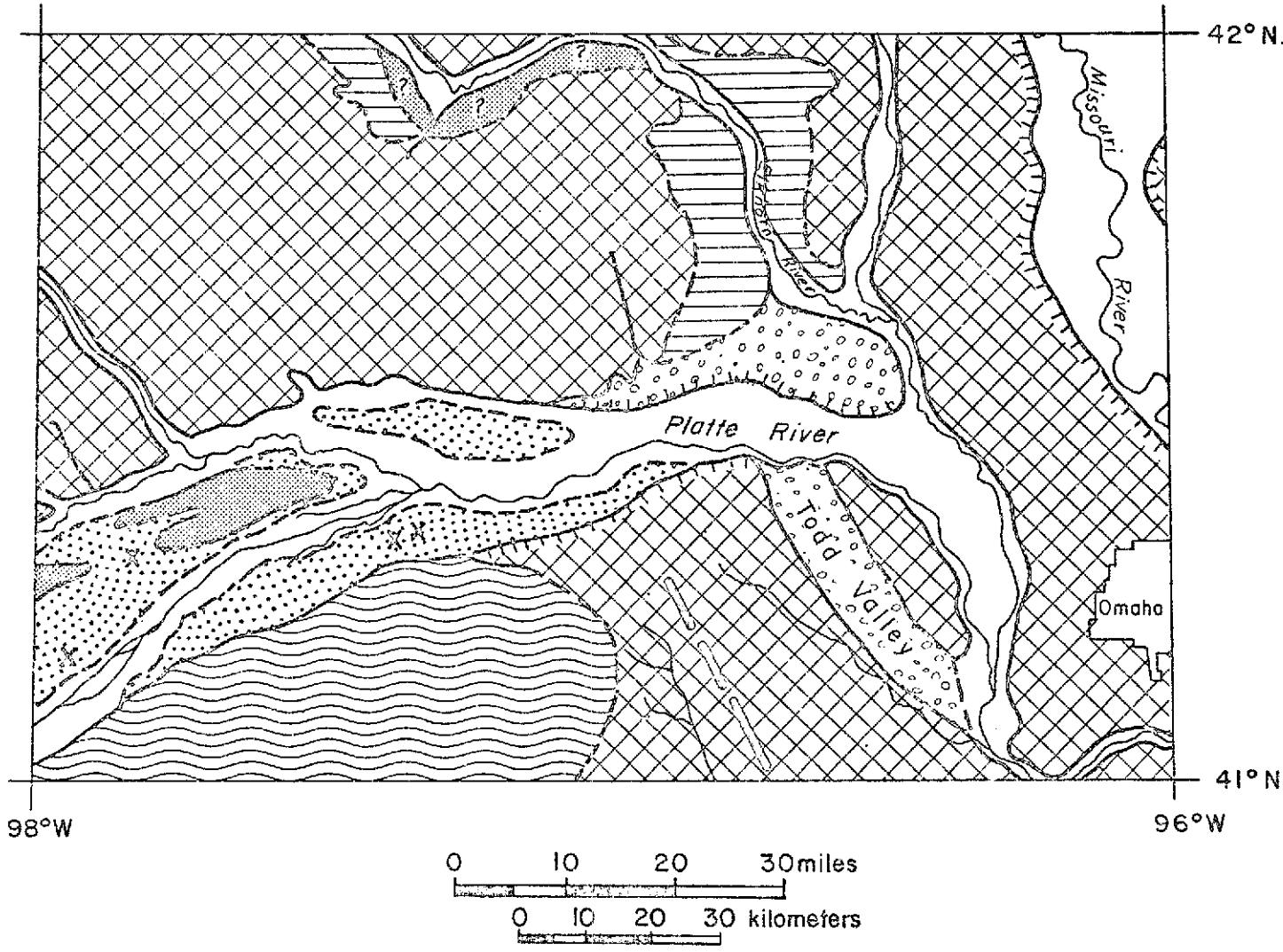


Figure 2. Phase-1 preliminary map of the Fremont, Nebraska, study area.

Explanation

Map unit	Landform characteristics	Land-use characteristics	Surficial-geologic materials
1.	Valley lowlands: flood plains and low terraces along major streams. Single heavy lines denote minor streams with distinguishable valley lowlands.	Fields moderate to very large in size and regular in shape. Mainly irrigated cropland, with some pastures and woodlots; woodlands occur locally along streams.	Alluvium of late Quaternary age. Higher terraces may be loess-mantled.
1a.	Possible higher terraces of the Platte River (the boundaries are poorly defined on the ERTS images) Tributary streams are parallel to the Platte for considerable distances.		
1b.	Well-defined higher terrace of the Platte River; includes the abandoned Todd Valley.		
2.	Plains with broad, nearly level uplands and widely spaced streams in shallow valleys.	Fields moderate to large in size and regular in shape. Mixture of irrigated and dry-land farming (cropland and pasture). No obvious center-pivot irrigation systems.	Probable extensive loess veneer, over other deposits of Pleistocene and older age.
3.	Intricately dissected plains. Closely spaced streams with narrow interstream uplands. Moderate local relief.	Fields of small to moderate size, commonly irregular, and in places only vaguely discernible. Mainly dry-land farms and pastures, with some irrigated cropland.	Probable extensive loess veneer, over other deposits of Pleistocene and older age.
3a.	Area of moderate dissection adjacent to the Elkhorn River; generally similar to unit 3, but the streams are farther apart and the interstream areas are broader and more undulating.	Like unit 3, except that the field patterns are somewhat more regular and better defined.	
4.	Sandhills. Tone and texture suggest isolated sandhills and gentle swell-and-swale topgraphy, but without large well-developed dune forms. X indicates possible sandhills (small, isolated, and poorly defined).	Few fields are discernible. Possibly rangeland with some dry-land and irrigated farming (pasture and cropland). A few center-pivot sprinkler irrigation systems are present. The area is characterized by a uniform gray tone on the imagery.	Eolian sand.
5.	Prominent escarpment.	Usually marked by a sharp change in tones and land-use patterns.	
6.	Possible loess-mantled, moraine-controlled drainage divide of middle Pleistocene age, indicated by drainage-pattern anomalies.	Images used (bands 5 and 7): 1022 - 16384 1060 - 16500 1076 - 16384 1095 - 16445 1095 - 16451	
7.	Minor streams with narrow valley lowlands distinguishable on ERTS images (see unit 1).		

Figure 2. Phase-I Preliminary Map of the Fremont, Nebraska, Study Area.



Davenport, Iowa-Illinois, study area.

The map of the Davenport 1° x 2° study area (fig. 3) is not strictly a phase-1 interpretation, because of first-hand knowledge of the area by the investigators. Thus, some phase-3 input is obvious, although it is not a completed phase-3 map.

The entire Davenport quadrangle has been glaciated repeatedly. The eastern and southeastern parts are underlain by drift of Illinoian age, a small east-central part by drift of Wisconsinan age, and the remainder by drift of Kansan and older age. In the west are the deeply dissected "Kansan till plains," and in the north is the gently rolling "Iowan erosion surface." The course of the Mississippi River through this area was repeatedly diverted by the various advances of the continental ice sheets. The effects of the later diversions are still visible in the landscape.

A possible moraine-controlled drainage divide of Illinoian age (map unit 6) is indicated by drainage-pattern anomalies. Previously mapped boundaries of glacial deposits and physiographic units, such as the boundary between the Kansan and "Iowan" surfaces, commonly are not clearly evident on the ERTS images. The reasons for the obscurity of these boundaries will be studied further and will be discussed upon completion of phase-3 studies in the area. ERTS frame 1037-16213 (29 August 1972) was compared with a 1969 Agricultural Stabilization and Conservation Service airphoto mosaic of Scott County, Iowa. The low-altitude photography was taken in late spring. The mosaic is at a scale of 1 inch equals 1 mile. The "Cleona channel"[1/] (fig. 3, map unit 1b) is evident on the ERTS imagery only where it influences major streams such as the Cedar and Wapsipinicon Rivers, to the south and north respectively. The broad sag (site of the "Cleona channel") between these two streams can be seen on the spring airphoto mosaic because of differences in soil properties and soil-moisture conditions, but it cannot be detected on the summer ERTS imagery. Also, the paha lineations that are prominent on the mosaic do not appear on the ERTS imagery. Paha is a term used in the Midwest for a linear, loess-covered ridge. The soils on the pahas commonly are distinctive but neither the soils nor the relief of the pahas visibly affects agricultural patterns on the summer satellite images. (Fall and winter images that are cloud- and haze-free have not been received.)

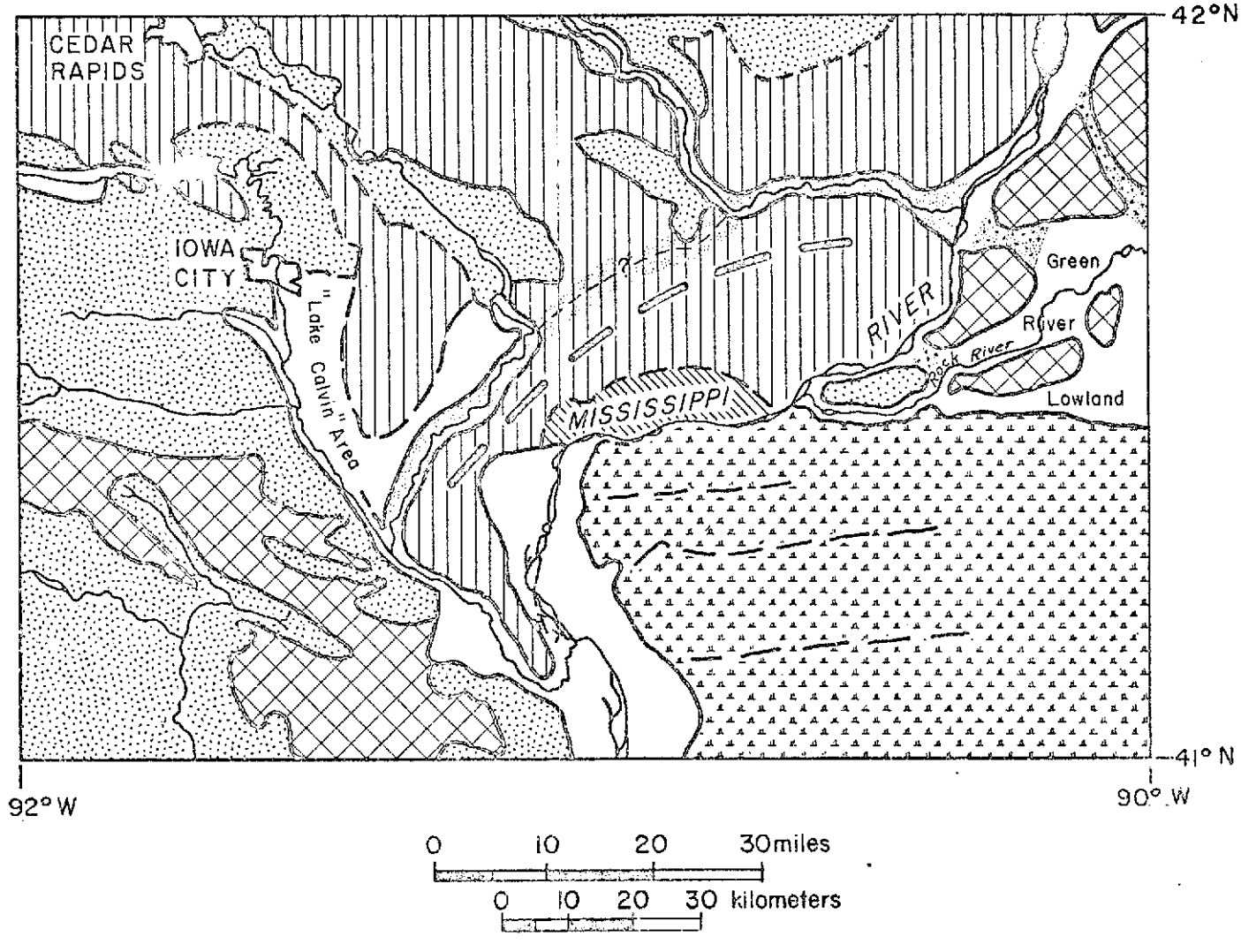
[1/] A former channel of the Mississippi River, formed initially by diversion of the river by an ice advance in Illinoian time, and reoccupied in Wisconsinan time.

Figure 3. Preliminary map of the Davenport, Iowa and Illinois, study area
Explanation

Map unit	Landform characteristics	Land-use characteristics	Surficial-geologic materials
1.	Valley lowlands; flood plains and low terraces.	Large to moderate-size, regular field patterns. Mainly cropland, some pasture. Woodlands common along streams.	Alluvial flood plain and terrace deposits of late Quaternary age. Some terraces may be loess-mantled. Underlain in places by lacustrine deposits of Wisconsin and Illinoian age in the Green River Lowland area, and possibly in the "Lake Calvin" area.
1a.	Nearly level lowlands, higher than unit 1. At present not inundated by major streams; at various times in the past however, they were flooded by the Rock and Mississippi Rivers.		Alluvial deposits of late Quaternary age.
2.	Moderately dissected plains. Larger valleys are broad and shallow and interstream areas generally are gently undulating. Moderate drainage density, local relief commonly 50 to 100 feet. Steep escarpments occur locally adjacent to major streams, such as the Mississippi River.	Large, regular field patterns. Mainly cropland, some pasture, and woodlands where steep slopes occur adjacent to major streams. Regular section-line rural-road pattern is clearly evident.	Loess mantle over drift of middle Pleistocene and older age.
3.	Mildly dissected plains, with nearly level interstream uplands. Widely spaced minor streams. Local relief generally 50 feet or less.	Large, regular field patterns. Cropland and pasture. Regular section-line road patterns.	Loess mantle over drift and alluvium of late Pleistocene and older age.
4.	Intricately dissected plains with closely spaced minor streams and narrow interfluve uplands. Local relief commonly 100 to 150 feet.	Small irregular field patterns. Mixed pasture, cropland, and irregular woodlots. Many farm ponds, compared to other areas. Woodlands along streams and bluffs.	Loess mantle over drift of late Pleistocene and older age.
4a.	Intricately dissected escarpment of the Mississippi River valley, with high drainage density and local relief.	Irregularly shaped pasture lands and extensive woodlands on the steep slopes along streams. Little distinguishable cropland.	Loess mantle over drift of middle Pleistocene and older age. Rocks of Pennsylvanian age outcrop extensively, giving distinctive topography.
5.	Plains marked by abnormally long, linear, parallel east-west major stream valleys, tributary to the Mississippi. Highly dissected, with about 150 feet of local relief, along these valleys, but the elongate intervening uplands are gently dissected with commonly less than 50 feet of local relief.	Uplands with moderately sized and regularly shaped fields, grading to smaller, irregular fields and woodlands along stream valleys.	Loess mantle over drift of Wisconsinan, Illinoian, and older age.
5a.	Abnormally long, linear, parallel, east-west streams, possibly indicate bedrock control.		
6.	Possible loess-mantled, moraine-controlled drainage divide of Illinoian age.		
7.	"Cleona channel," a channel of the Mississippi River during both Illinoian and Wisconsinan time. Its surficial expression is represented by the stippled portions of two areas of valley lowlands, and the intervening stippled area, which is not identifiable on ERTS imagery.		
8.	Lakes and reservoirs.		

Images used (bands 5 and 7):
1036-16154
1037-16213
1073-16212

Figure 3. Preliminary Map of the Davenport, Iowa and Illinois, Study Area.



Plans for the next reporting period.

Study and interpretation of the ERTS imagery for the various study areas within the project will continue, under the six-phase program of analysis. Results from the project will be reported at the Symposium on ERTS-1 Investigations at the Goddard Space Flight Center, in early March. In addition, office and field conferences will be held with personnel of some of the cooperating State geological surveys.

E. Significant scientific results and their practical applications.

This project is testing the applicability of ERTS-1 imagery for synoptic identification and mapping of Quaternary geologic and geomorphic units ("geologic-terrain" units) in the Midwest-Great Plains, including end moraines of the last glaciation, terrace sequences along main rivers, relicts of ancient (middle and early Pleistocene) glacial moraines, and valleys filled by younger glacial drift, loess, or eolian sand.

The main landform associations and larger landforms are readily identifiable on the better images and commonly the gross associations of surficial Quaternary deposits also can be determined primarily by information on landforms and soils (obtained by analysis of stream dissection and drainage and stream-divide patterns, land-use patterns, etc.). Maps showing the Quaternary geologic-terrain units that can be distinguished on the ERTS-1 images are being prepared for study areas (mostly 1° x 2° in size, several in each State) in Illinois, Iowa, Missouri, Kansas, Nebraska, and South Dakota.

Preliminary maps at 1:1 million scale are included for three of the study areas: the Grand Island and Fremont, Nebraska, and the Davenport, Iowa-Illinois, 1° x 2° quadrangles. These maps exemplify the first phase of investigations, which consists of identifying and mapping landform and land-use characteristics and geologic-surficial materials directly from the ERTS-1 images alone, with no additional information. These maps show that commonly the boundaries of geologic-terrain units can be delineated more accurately on ERTS-1 images than on topographic maps of 1:250,000 scale. Anomalous drainage patterns and stream-divide relationships in the Fremont and Davenport quadrangles may be relicts of moraines of middle or early Pleistocene age. In the Fremont quadrangle, the infrared bands of images taken in October immediately after moderate rains show soil differences especially well, making it easier to map the gross associations of soils and surficial deposits. This may have useful application for improving multispectral techniques for detailed mapping of soils and surficial deposits.

Category designation:

1O, 2A, 3I.

F. Published articles, etc. released during the reporting period. None.

G. Recommendations. None.

H. Changes in standing order forms. None.

I. ERTS image descriptor forms. See following attachment.

J. Data request forms submitted. Jan. 18 and Feb. 5, 1973.

K. N/A.

Appendix A

The six-phase program of interpretation of ERTS-1 data that is scheduled for this project:

Phase 1 consists of preliminary mapping of the pertinent geologic and geomorphic features using only the ERTS-1 imagery.

Phase 2 involves compilation of available published and unpublished ground truth data (geologic, soil, topographic, etc.), preferably on a map of the same scale as that prepared for phase 1, without using ERTS data.

Phase 3 is a comparison of phase 1 and 2 products, with additional photointerpretation, to prepare an "enhanced information" map (at scales ranging from 1:1 million to 1:250,000, as appropriate), noting any differences and anomalies.

Phase 4 consists of additional analysis made from ERTS repetitive coverage of the area, noting added information (at least the differences in information content) gained from time-variant phenomena such as changes in vegetation, soil moisture, snow cover, and plowing of croplands.

Phase 5 consists of appropriate field studies to obtain necessary additional ground-truth data, particularly to evaluate anomalies and interesting new features found in phases 3 and 4.

Phase 6 is the delineation of the new information detected from the ERTS imagery.